Reference-Free Pupillary Distance Estimation

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Problem Statement

Turn an everyday selfie into a reliable millimeter-level PD estimate that works in real-world conditions.

There are thousands of glasses available online, but a key metric for determining proper fit is Pupillary Distance (PD). In-store, measuring your PD is simple, but for users shopping online from their couch, it becomes much more challenging. Modern shoppers want a quick, seamless experience, without the hassle of holding a reference card to their face. To address this, this project aim to replace the geometric approximations used in traditional reference-free methods with a biometric dual-reference model, delivering millimeter-level accuracy without requiring any external physical reference.

Methodology

- **Input**: Single selfie image
- **Pipeline**:
  - Validates image quality
  - Enhances poor images
  - Detects facial landmarks
  - Calculates PD using references from detected landmarks
  - Computes confidence score through each stage
- **Output**: Final PD estimation + Confidence Score

Accept

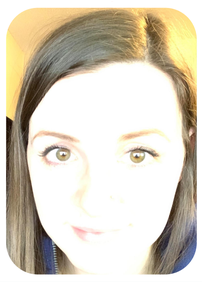
Reject

Reject

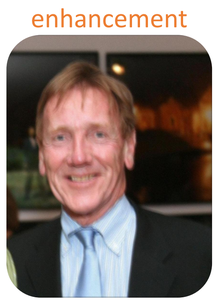
- Face detection and eye detection by **HaarCascade**
  - Accept: Visibility of face AND visibility of eyes AND number of detected eyes = 2
- Face tilt detection:
  - Reject: Face yaw ratio > 0.1
- Face roll detection:
  - Reject: Face tilt > 30 degrees

Low Contrast

Overexposed



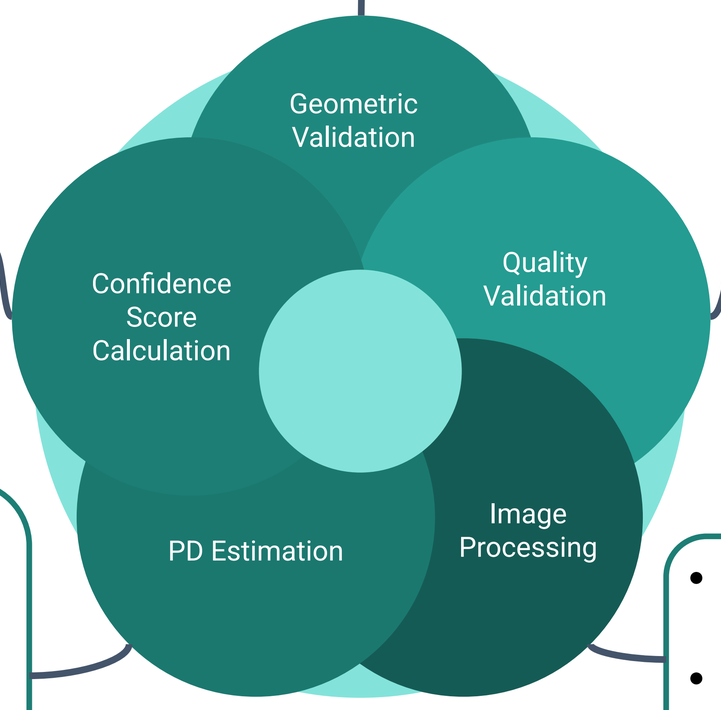
Need enhancement



Final Output

```
{
  "PD": {
    "L": "30.5",
    "R": "30.5"
  },
  "ConfidenceScore": {
    "score": "0.93",
    "classification": "High"
  }
}
```

- Combines image quality, face geometry, landmark and PD checks into a **single score [0–1]**
- Higher score → reliable input
- Lower score → low confidence / reject measurement



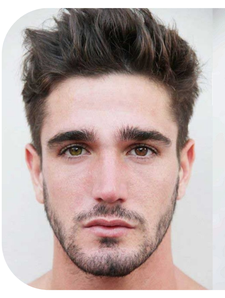
- Sharpness of the image:
  - Reject: too blurred images
- Exposure of image:
  - Checks the proportion of the clipped pixels in image (the px value is too high/low and, thus, it is represented by the highest/lowest value). OR calculates “Proportion of Loss”
  - Reject: images with high loss
- Contrast of image:
  - Reject: images with indistinguishable details

Landmark Detection

- Landmark detection of the face:
  - Detect 478 facial landmarks (including iris points) via **MediaPipe**
- PD calculation:
  - Converting pixel distances to millimetres using a dual-reference scale (iris diameter + inner-canthal width), averaged to cancel their opposing biases.

- Group 1 - Contrast & Exposure:
  - CLAHE: fixes uneven lighting across face
- Group 2 - Denoise & Blur & Glare:
  - Denoising, Blur reduction, Glare removal

Before



After

Results

Difference <= 2mm Difference > 2mm Processed > Raw

	status	PD mm processed	left processed	right processed	PD mm raw	left raw	right raw	confidence score processed	confidence score raw	original pd	difference processed	difference raw	error msg
image9_60.jpg	SUCCESS	60.8	33.2	28.0	59.8	32.3	27.8	0.91	0.91	60	-0.8	0.2	[]
image8_61.jpg	SUCCESS	62.0	31.0	31.3	60.8	30.2	30.8	0.93	0.93	61	-1.0	0.2	[]
image22_R_29_L_30.jpeg	SUCCESS	60.3	29.7	31.0	60.0	30.0	30.5	1.0	1.0	59	-1.3	-1.0	[]
image12_62.jpg	SUCCESS	63.4	31.5	32.3	62.7	31.5	31.5	0.93	0.93	62	-1.4	-0.7	[]
image11_62.jpg	SUCCESS	63.8	31.9	32.4	62.6	31.3	31.7	0.93	0.93	62	-1.8	-0.6	[]
image21_R_29_L_30.jpeg	SUCCESS	61.0	30.2	31.2	61.2	30.4	31.3	0.93	0.93	59	-2.0	-2.2	[]
image20_R_29_L_30.jpeg	SUCCESS	61.0	30.2	31.2	61.2	30.4	31.3	0.93	0.93	59	-2.0	-2.2	[]
image1_R_31:5_L_31:5.jpg	SUCCESS	62.5	31.6	31.2	61.5	31.0	30.7	0.97	1.0	63	0.5	1.5	[]
image10_60.jpg	SUCCESS	59.4	31.6	28.0	60.3	31.7	28.9	1.0	0.93	60	0.6	-0.3	[]
image19_R_32_L_30_5.jpeg	SUCCESS	62.0	31.3	30.9	61.4	30.8	30.7	0.93	0.93	62.6	0.6	1.2	[]
image5_R_32_L_30:5_glasses.jpg	SUCCESS	61.6	31.0	30.7	59.7	30.2	29.5	0.9	0.93	62.5	0.9	2.8	[]
image7_R_32_L_30:5.jpg	SUCCESS	61.5	30.9	30.6	60.6	30.8	29.9	0.97	1.0	62.5	1.0	1.9	[]
image4_R_32_L_30:5.jpg	SUCCESS	60.8	30.7	30.2	60.0	31.4	28.6	1.0	1.0	62.5	1.7	2.5	[]
image2_R_30:6_L_32:6.jpg	SUCCESS	61.3	32.1	29.5	60.9	31.6	29.6	0.95	0.98	63.1	1.8	2.2	[]
image17_R_31_L_32.jpeg	SUCCESS	60.7	30.3	30.5	60.5	29.8	30.8	0.93	1.0	63	2.3	2.5	[]
image6_R_32_L_30:5.jpg	SUCCESS	59.8	29.9	30.0	58.4	29.6	28.9	0.97	1.0	62.5	2.7	4.1	[]
image18_R_31_L_32_glasses.jpeg	SUCCESS	60.3	30.1	30.3	58.7	29.0	29.8	1.0	1.0	63	2.7	4.3	[]
image14_63:5_glasses.jpg	SUCCESS	59.3	30.2	29.3	60.3	30.7	29.8	1.0	1.0	63.5	4.2	3.2	[]
image3_R_31_L_32_glasses.jpg	SUCCESS	58.0	29.4	28.9	58.5	29.7	29.1	0.97	0.97	63	5.0	4.5	[]
image15_63:5.jpg	SUCCESS	58.3	28.8	29.9	58.9	29.2	30.1	1.0	1.0	63.5	5.2	4.6	[]
image13_63:5.jpg	SUCCESS	58.3	28.9	29.8	56.7	27.8	29.2	1.0	1.0	63.5	5.2	6.8	[]
image16_63:5.jpg	SUCCESS	58.2	28.3	30.1	58.9	29.1	30.0	1.0	1.0	63.5	5.3	4.6	[]

Special thanks to Pickzai, family, and friends whose participation helped us gather the test results needed for pipeline improvements.

Future Works

- Perform the **enhancement of the images only on a problematic features** (e.g., for blurred image is applied sharpness filter only.)
  - **Solution**: Conduct a research on different images with different stages of degradation to find what quality parameter’s value causes the accuracy decrease. Then classify the input images based on this knowledge and apply the corresponding filters
- Implement **stricter image filtering** to flag inputs that are likely to yield highly inaccurate PD estimations.
  - **Solution**: Run the pipeline across a broader variety of images to identify the specific visual conditions that lead to false results.
- **Enhance the machine learning model** to improve landmark detection accuracy down to the millimeter level.
  - **Solution**: Fine-tune the current model or train a new model specifically to detect stricter landmark boundaries.

Conclusion

Reference-free PD estimation from ordinary selfies is affected by **image quality, face geometry and landmark detection errors**.

To address this challenge, we developed an end-to-end pipeline that integrates **image quality and geometric validation, image enhancement, facial and iris landmark detection, dual-reference (face and iris) PD estimation, and confidence scoring**. The system estimates PD from standard images while quantifying input reliability and flagging conditions that could degrade measurement accuracy.

However, the current pipeline has **several limitations** due to a small test dataset and a tight development timeframe. While the system achieves an average error rate under 2 mm, there is still room for improvement in validating input images and reducing estimation errors further.

Limitations

- The system struggles significantly with selfies featuring glasses.
  - Higher errors occur whenever glasses are present, yet the current pipeline cannot effectively filter these images.
- Confidence score does not directly reflect the accuracy of the PD measurement.
  - Confidence score was calculated based on image quality metrics rather than actual PD accuracy.
  - While this helps filter poor quality images, it cannot guarantee millimeter-level PD precision.
- Image processing filters improve visibility but may introduce slight pixel-level distortions that affect PD calculations on borderline images.
  - Performing image processing on every frame is computationally expensive.
  - Image processing does not guarantee an improvement in PD estimation and can sometimes even worsen accuracy compared to using raw images.

References:

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